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PARTICULATE AND FLUORIDE EMISSIONS CONTROL, ANACONDA ALUMINUM COMPANY, COLUMBIA FALLS, MONTANA

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PARTICULATE AND FLUORIDE EMISSIONS CONTROL ANACONDA ALUMINUM COMPANY COLUMBIA FALLS, MONTANA

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SUMMARY

The Anaconda aluminum reduction facilities at Columbia Falls, Montana currently emit approximately 367 pounds of particulate and 103 pounds of fluoride per hour. This is equivalent to 17.8 and 5.0 pounds per ton of aluminum respectively, for particulate and fluoride. The breakdown of the emissions from the primary collection device and the roof monitors as reported by Anaconda is:

Source	Total fluoride, lb/hr	Total particulate, lb/hr
Primary	21	6
Roof Monitors	82	361
Total	104	367

Allowable fluoride emissions under Montana's regulation are 36.0 pounds of total fluoride (1.74 pounds per ton of aluminum). Allowable particulate emissions range from 46 to 522 pounds per hour (2.2 to 25.3 pounds per ton of aluminum) depending on how the process weight regulation is interpreted.

Secondary control devices were investigated for use at the Anaconda reduction facility to reduce emissions from the roof monitors. No significant improvement could be made in the capture or removal efficiency of the existing primary control system.

A roof mounted, powered spray screen was studied to determine the feasibility of installing such a control system, and its

capital cost, annual operating cost, and collection efficiency. Devices similar to this have been installed at other similar smelters. This study yielded the following data:

Capital cost	$20,688,000
Annual operating cost	$ 6,114,000
Fluoride removal efficiency	80%
Particulate removal efficiency	48%

The capital costs are equal to $115 per ton of installed aluminum production capacity, and the operating costs amount to about 1.7 cents per pound of aluminum produced.

Emissions after installing this powered spray screen control system would be 37 pounds per hour of fluorides and 194 pounds per hour of particulate (1.8 and 9.4 lb/ton of aluminum respectively). These emissions would meet the fluoride regulation and could meet the particulate regulation, if a process is defined as a single cell or a set of 20 cells connected to a single primary control system.

The secondary system could be installed within a 28-month time period. No process shut-downs would be required to install the secondary control system. Recycle and neutralization of the scrubbing water would not require disposal of any liquid stream. Sludge generated in the system could be stored on existing plant property.

1.0 INTRODUCTION

This report presents an assessment of the feasibility of reducing atmospheric emissions of fluorides and particulate matter from the Anaconda Aluminum Company plant in Columbia Falls, Montana. Information for this study was obtained from the Montana State Department of Health and Environmental Sciences, from Anaconda Aluminum Company personnel, and from control equipment vendors and literature references.

This plant has installed equipment to reduce atmospheric emissions, and is currently researching methods of further reducing these emissions. This report describes the plant and its emissions, discusses the type of controls which could be installed with currently available and demonstrated equipment; present a preliminary design of a secondary control system and the approximate cost of the equipment, and shows the time required for installation.

2.0 PROCESS DESCRIPTION AND EMISSIONS

2.1 PROCESS DESCRIPTION

The basic process used for producing raw aluminum metal in all plants in the U.S. consists of the electrolytic dissociation of alumina (Al_2O_3) dissolved in a molten bath of cryolite (Na_3AlF_6). Oxygen released in this process reacts with the carbon anode to form carbon dioxide and some carbon monoxide. The molten aluminum settles to the bottom of the cell, directly above the cathode.

Three types of cells or pots are used to accomplish this reaction; namely the pre-bake, and the vertical and horizontal Stud Soderberg design. These cells all operate under the same principle, but they differ in anode configuration.

The Anaconda Columbia Falls plant, with a design capacity of 180,000 tons of aluminum per year, has five pot lines consisting of 120 Vertical Stud Soderberg (VSS) pots or cells in each line. These five pot lines are contained in ten large buildings which are approximately 1123 feet long, 87 feet wide and 39 feet high. Figure 2.1 illustrates a typical view of a pot room at the Anaconda facility.[1] Each pot operates at a bath temperature of approximately 960°C and a current of 107,500 amps. Average plant power consumption is approximately

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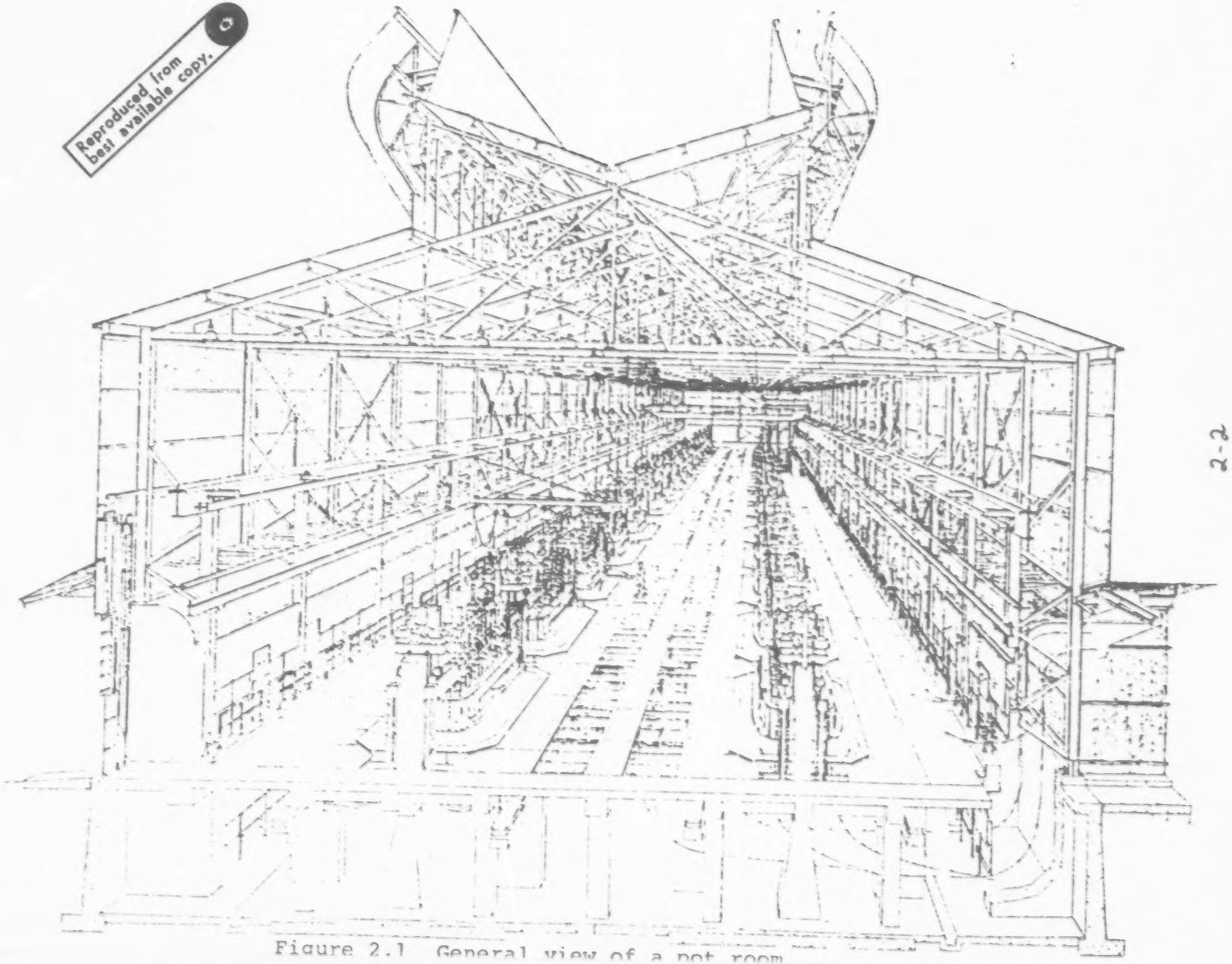

Figure 2.1 General view of a pot room

8,800,000 kilowatt hours per day. In addition to the cell rooms, the plant has an anode paste mixing process, aluminum casting area, and alumina receiving area.

In the VSS type of cell, the steel studs carrying the electrical current project vertically into the anode through the green or unbaked paste down into the baked portion of the anode as shown in Figure 2.2. The cathode consists of the lower carbon cell lining with a steel bar embedded in it to carry the current. Long rows of cells connected electrically in series form a production "line".

The cell cavity contains the molten bath consisting of approximately 90 percent cryolite (Na_3AlF_6), five to six percent fluorspar (CaF_2) and two to seven percent alumina (Al_2O_3). The molten bath is covered by a crust of frozen electrolyte and alumina. This crust diminishes heat loss from the top of the cell, reduces atmospheric emissions, and protects the anode from oxidation. Periodically part of the crust is manually broken and stirred into the bath, and fresh alumina is added to form a new crust.

As the anode carbon reacts with oxygen at the bath surface, additional anode material (green paste) is added manually to the top of the cell to replenish the anode.

The electrical current decomposes the alumina in solution in the bath. Aluminum is deposited as molten metal on the bottom of the cell, and the oxygen is liberated at the anode, where it reacts to form carbon oxides which are released in the cell gases. The aluminum at the operating temperature of the cell is slightly more dense than the molten

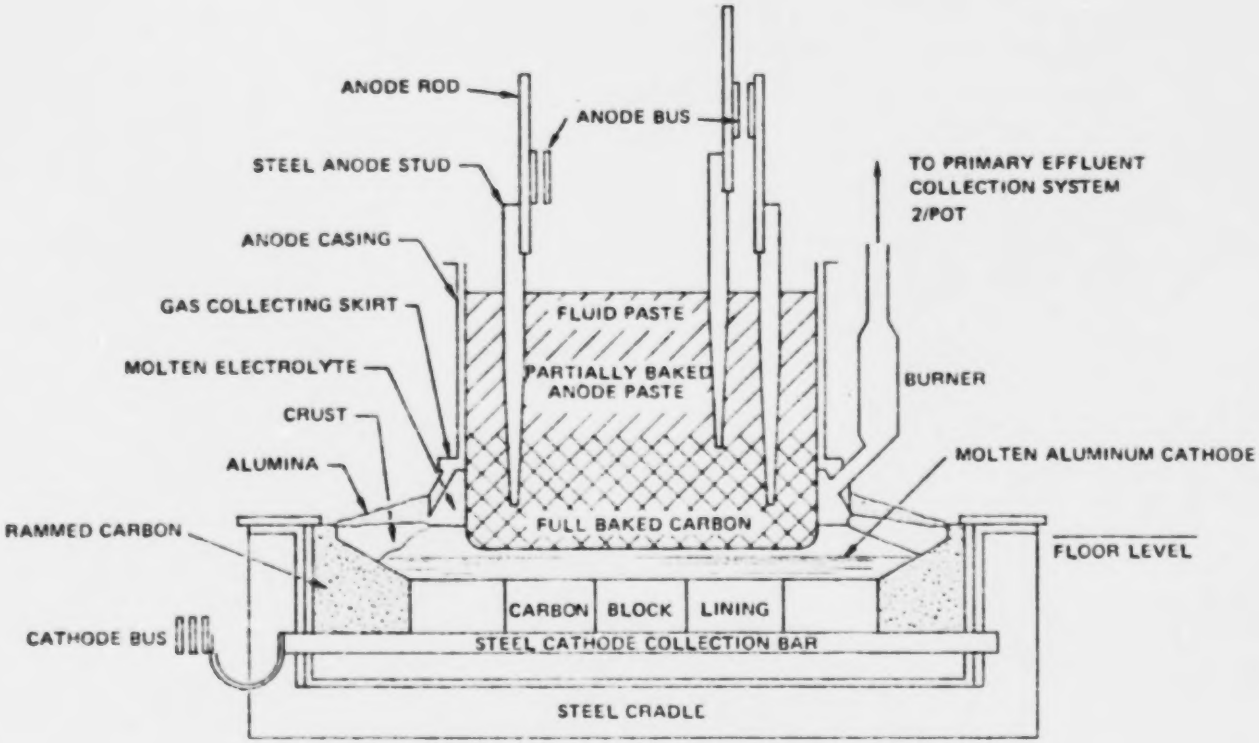

Figure 2.2 Vertical Stud Soderberg aluminum reduction cell.[2]

bath and forms a metal pad on the bottom of the cell.

Approximately once every 24 hours, molten aluminum is siphoned from the cell into an insulated steel container and transferred to the cast house.

2.2 POLLUTION CONTROL SYSTEM FOR THE REDUCTION CELLS

Hydrocarbons, carbon monoxide, fluorides, and particulate matter are emitted during the electrolytic reaction. Particulate and fluorides (both solid and gaseous) are the primary pollutants. Total fluorides released in the cell amount to approximately 50 pounds per ton of aluminum produced (44 pounds per cell per day).[3] Approximately 90% of this fluoride is reported to be in the gaseous form. Emissions of total particulate (including solid fluorides) have not been reported but are probably on the order of 100 pounds per ton of product. Approximately 70% of these pollutants are picked up by the primary cell ventilation system. Condensible organic matter (tar) escapes from the top of the anode. Additional particulate and fluoride emissions escape through breaks in the crust around the gas collecting skirt.

As shown in Figure 2.2, each cell is equipped with two vertical risers which exhaust 300 cfm each to a control system. Atmospheric emissions from the bath which escape this primary control system are vented into the cell room and on up through the roof openings. Openings in the room walls and floor enable ambient air to flow through the building.

Emissions picked up from the cells are controlled by venting the gases through an afterburner, a multi-cyclone, and a

venturi scrubber followed in series by a packed bed scrubber containing plastic saddles. Twenty cells are tied into each scrubber system with a vent gas flow of 600 cfm per cell, yielding a total flow of 12,000 cfm per vent system. Each scrubbing system has a total pressure drop of 40 inches of water. Water is the scrubbing medium in the venturi and packed bed scrubber. This water is treated with lime to control pH and remove fluorides. The water is then clarified and the overflow recycled to the scrubbers. No waste water leaves this system. Wet sludge from the clarifier is removed periodically and disposed of on-site. Dust collected in the multi-cyclone is recycled to the cells. The afterburner ignites any carbon monoxide and hydrocarbons in the vent gas stream.

This scrubbing system has an estimated efficiency of 98 to 99% in removing total fluorides.

No control systems are used on the roof ventilation system.

2.3 ATMOSPHERIC EMISSIONS

Emission rates from this plant have varied during the life of the plant, as new lines were brought into production and as control equipment was added or modified. Figure 2.3 shows the trend in fluoride emissions since plant start-up in 1955. This figure shows a peak emission rate during 1968 to 1971 of approximately 7500 pounds per day. The peak emission occurred because of the start-up of new lines, associated operating problems, and use of only a medium efficiency scrubber on the primary control system. Starting in 1971, a more efficient primary control system was installed which reduced fluoride emissions from all the cells to about 494 pounds per day. The emissions escaping into

the room were also reduced because of better operating practices and better fume control around each cell. The remaining emissions of 1978 pounds per day currently escape through roof monitors.

The trend in particulate emissions is shown in Figure 2.4. Particulate emissions paralleled fluoride emissions and varied with the start-up of new lines and the installation of improved control equipment. Emissions are currently estimated to be 8799 pounds per day, of which 8650 pounds escape from the roof monitors.

Total average emissions to the atmosphere during 1973 are summarized in Table 2.1. Emissions are also shown in Figures 2.3 and 2.4 that would result if a control system as described in Section 4.0 of this report were installed to reduce emissions from the roof monitors. Total fluoride emissions at that time would be about 37.1 pounds per hour (20.6 pounds per

Table 2.1. ATMOSPHERIC EMISSION RATE IN 1973

Emission source	Plant emissions					
	Fluoride			Particulate		
	lb/day	lb/hr	lb/ton[a]	lb/day	lb/hr	lb/ton[a]
Primary vent systems - 30 units at 12,000 cfm each	494	20.6	1.0	149	6.2	0.3
Roof Monitors - 10 at 2,550,000 scfm	1978	82.4	4.0	8650	360.5	17.5
Total	2472	103.0	5.0	8799	366.7	17.8

a) Based on average production rate of 20.6 tons per hour for entire plant with all lines in operation. Emission data reported by Anaconda Aluminum Company, July 25, 1973.

Aluminum Produced	Year	F Emissions	#/ton of Al.	Pot Lines	Controls Primary	Secondary
200 tons/day	1955	1900 #/day	9.5	2	Multiclone & wet scrubber=1200 #F/day	None=700 #F/day
300 tons/day	1965	3600 #/day	12.0	3	Multiclone & wet scrubber=1800 #F/day	None=1800 #F/day
500 tons/day	1968	7500 #/day	15.0	5	Multiclone & wet scrubber=3000 #F/day	None=4500 #F/day
500 tons/day	1971	2472 #/day	5.1	5	Venturi scrubbers = 494 #F/day	None=1978 #F/day
500 tons/day	1975	890 #/day	1.8	5	Venturi scrubbers= 494 #F/day	Roof scrubbers= 396 #F/day

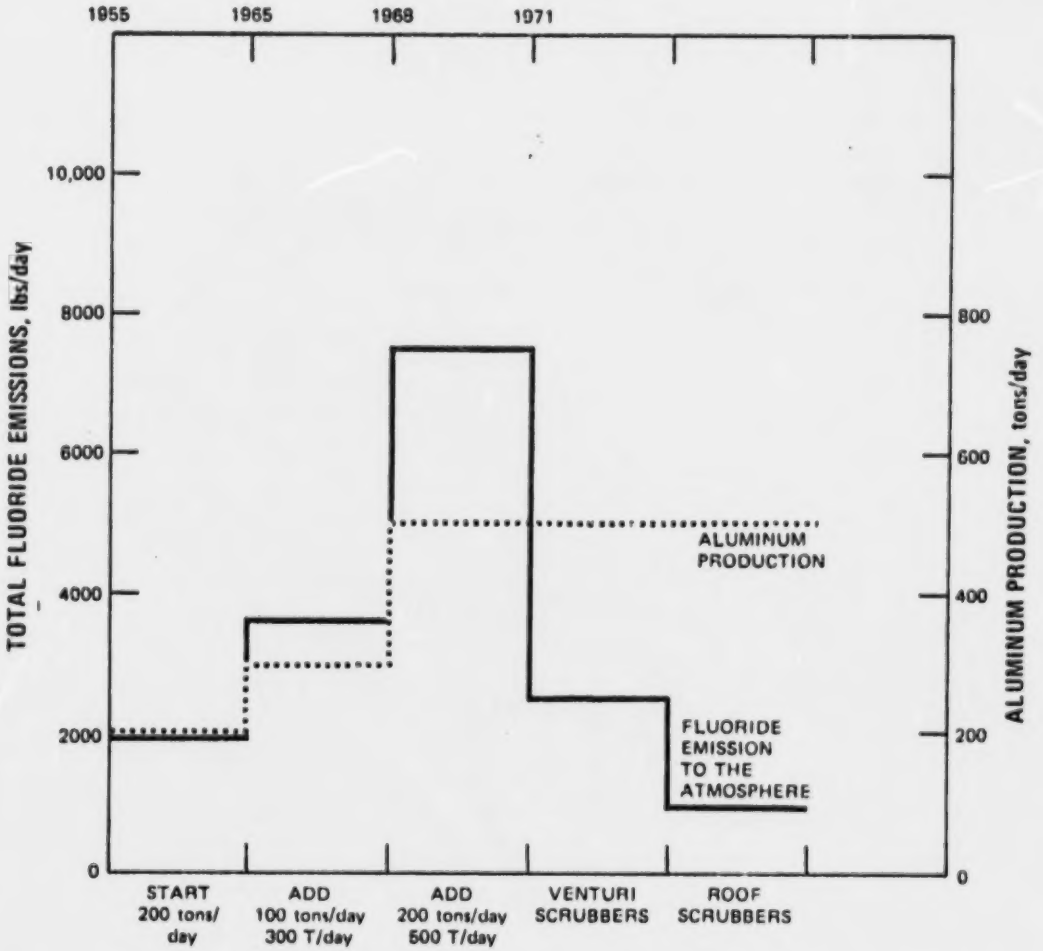

Figure 2.3 Estimated fluoride emission rates and aluminum production at Anaconda plant in Columbia Falls, Montana. (Based on data in Ref. 4)

Aluminum Produced	Year		#/ton of Al.	Pot Lines	Controls Primary	Secondary
200 tons/day	1955	3950 #/day	19.75	2	Multiclone & wet scrubber=750 #/day	None=3,200 #/day
300 tons/day	1965	5925 #/day	19.75	3	Multiclone & wet scrubber=1125 #/day	None=4800 #/day
500 tons/day	1968	10525 #/day	21.3	5	Multiclone & wet scrubber=1875 #/day	None=8650 #/day
500 tons/day	1971	8799 #/day	17.8	5	Venturi scrubber= 149 #/day	None=8650 #/day
500 tons/day	1975	4649 #/day	9.4	5	Venturi scrubber= 149 #/day	Roof scrubber= 4500 #/day

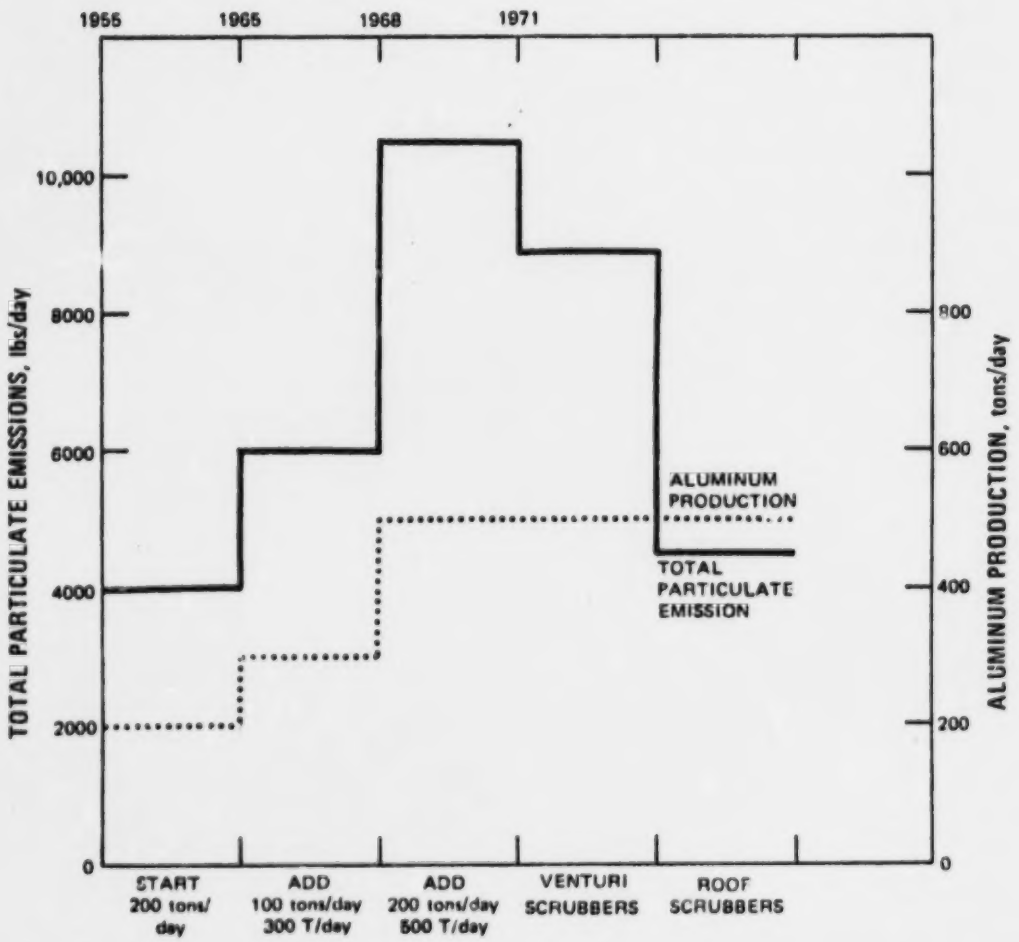

Figure 2.4 Estimated particulate emission rates and aluminum production at Anaconda plant in Columbia Falls, Montana. (Based on data in Ref. 4)

hour from the 30 primary systems and 16.5 pounds per hour from the roof monitor controls). Particulate emissions would be 193.7 pounds per hour (6.2 pounds from the existing primary system and 187.5 pounds from the roof monitor control system).

2.4 ALLOWABLE FLUORIDE AND PARTICULATE EMISSIONS

Montana Regulation 16-2.14(1)-S14080 states that the amount of fluorides emitted from this plant may not exceed 0.060 pound per hour per reduction cell. At Anaconda's Columbia Falls facility, 36 lb/hr or 1.74 lb/ton of aluminum, of both gaseous and particulate fluorides are allowed, since there are 600 reduction cells. There is also a 40 lb/hr maximum limit regardless of the number of cells.

Particulate regulations at this time can be interpreted to give various allowable emissions depending on how a process is defined.

Regulation 16-2.14(1)-S1430 limits particulate emissions according to the amount of material utilized in a process. However, at a primary aluminum plant, a process can be defined as; 1) the entire plant, 2) a pot line, 3) the number of cells vented to one primary control device, and 4) a single cell. The Anaconda plant's smelting cells use a total of approximately 59 tons of material per hour. This is equivalent to 11.8 tons per pot line, 1.97 tons per scrubber system (20 cells), or 0.0908 ton per single cell. Allowable particulate emissions for each of the process weights are presented in Table 2.2, and are seen to vary from 46.1 lb/hr to 522 lb/hr depending on how a process is defined.

Table 2.2. ALLOWABLE PARTICULATE EMISSIONS

Process unit	Process weight, tons/hr	Allowable emissions per unit, lb/hr	Total allowable emissions	
			lb/hr	lb/ton
Plant	59.0	46.1	x 1 = 46.1	2.2
Line	11.8	20.8	x 5 = 104	4.9
Control system	1.97	6.4	x 30 = 192	9.3
Cell	0.0908	0.87	x 600= 522	25.3

3.0 ADDITIONAL EMISSION CONTROLS

The primary control system presently operates at fairly high levels of both cell capture and emission control efficiency. However, even with 100% emission control efficiency on the primary system, the fluoride emission standard would not be met, and the particulate standard could only be met when a single cell is defined as a process.

Emissions from the cells occur during anode stud replacement, crust breaking, and from baking the green paste in the anodes. These emissions are not controlled. A secondary control system designed to treat the gases escaping through the roof could reduce fluoride emissions to the allowable level. Particulate emissions would also be reduced, and could meet the particulate standard if a process is considered as a single cell or a set of 20 cells tied into a primary control system.

3.1 DESCRIPTION OF AVAILABLE SECONDARY CONTROL SYSTEMS

A number of secondary control systems are described in this section to illustrate the types of systems available. Sections 4.0 and 5.0 describe one of these systems to show how it would fit into the Anaconda plant, and what it would cost. Detailed costs on the other systems were not developed. However, final installed costs for other systems would not vary more than about $\pm$30% from the one selected as an example.

3.1.1 Floating Bed Scrubber[5]

The floating bed scrubber is a special type of packed bed scrubber in which the packing consists of hollow plastic spheres, approximately 1.5 inches in diameter, buoyed and agitated by the rising effluent gas stream. Scrubbing liquor flows down through the bed carrying away the collected particulate and dissolved gas. The typical unit for secondary control systems as shown in Figure 3.1, is one stage with a pressure drop of approximately 1.5 inches. Liquid flows are approximately 3.0 gallons per 1000 cubic feet of gas flow. Removal efficiencies are 70% for solids and 87% for fluorides.

One floating bed scrubber for secondary service has been installed on a Vertical Stud Soderberg smelter in Sundsvall, Sweden. Installed costs for this system are somewhat higher than spray systems. However, less water is required to accomplish collection, and operating costs are therefore similar to other systems.

3.1.2 Crossflow Packed Bed Scrubber

Packed bed wet scrubbers remove entrained particulates by inertial impingement against wet surfaces of packing material and remove HF gas by absorption in the liquid film. Packed bed scrubbers generally show relatively poor efficiency in controlling the very small particulates which contribute to visible emissions.

The crossflow configuration shown in Figure 3.2 may have advantages over the older vertical packed tower arrangement where the gas flows up countercurrent to scrubbing liquor which drips down through the bed. The crossflow bed has a lower pressure

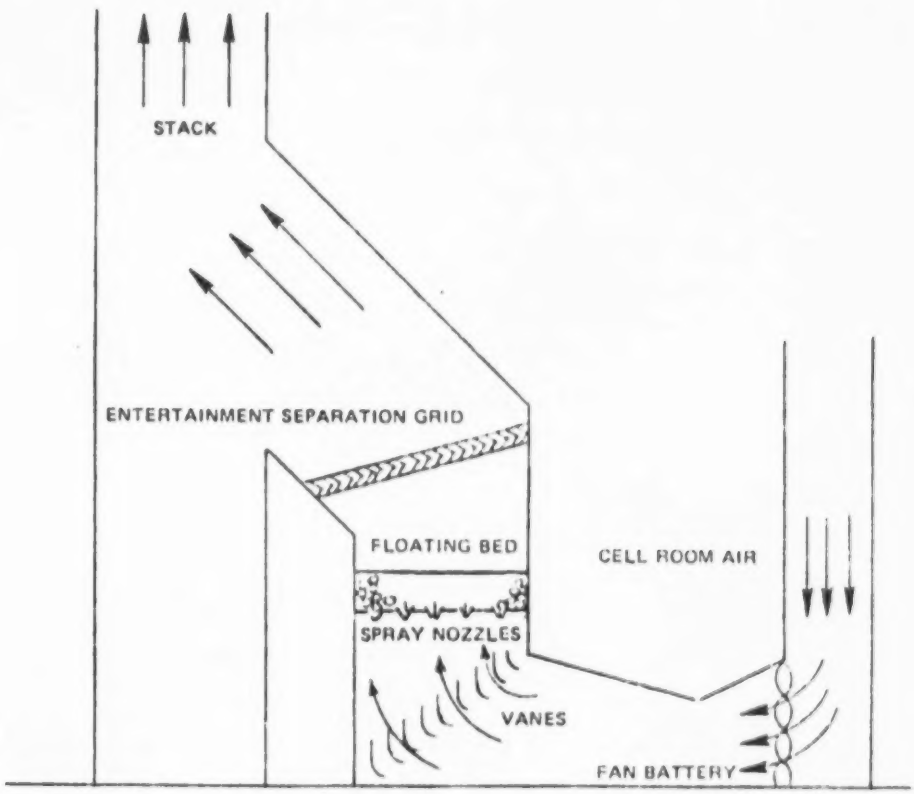

Figure 3.1 Floating bed scrubber in secondary VSS service.[5]

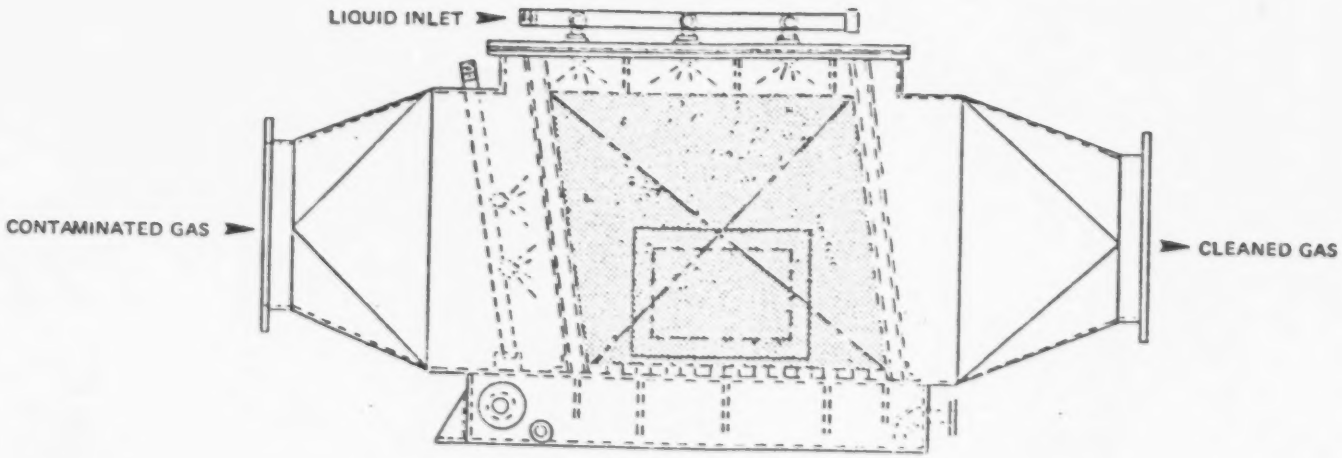

Figure 3.2 Crossflow packed bed scrubber.[5]

drop as compared to a vertical bed of equal capacity because the liquid and gas streams interact at right angles rather than in direct opposition. Further, this flow geometry is responsible for the non-flooding characteristics of the crossflow bed. The first foot or so of packing may be washed with considerably more liquor than the back part of the bed. This turbulent washing action removes most of the particulate and prevents plugging. In addition, if the gas can be cooled below its dewpoint early in the bed, condensation nuclei formed downstream will provide additional sites for absorbing gas and particulates.

The crossflow packed bed is used in one secondary application on pre-bake lines. Pressure drops are approximately 1.5 inches of water. Collection efficiencies are estimated at 90% for fluorides and 60% for particulates.

3.1.3 Spray Screen Scrubber

The term spray screen scrubber is applied to wet scrubbing equipment in which the liquor is sprayed into an effluent gas stream and onto screens or open mesh filters enclosed in a plenum chamber. The assembly also usually includes a mist eliminator. Figures 3.3 and 3.4 show typical configurations of spray screen scrubbers as applied to pot rooms.

The low gas pressure drop across the spray screen scrubbers and the relatively low power cost make these devices attractive for pot room scrubbing service.

Removal efficiencies are estimated to be 48% for particulate and 80% for fluorides. Pressure drops are 1.0 to 2.0 inches

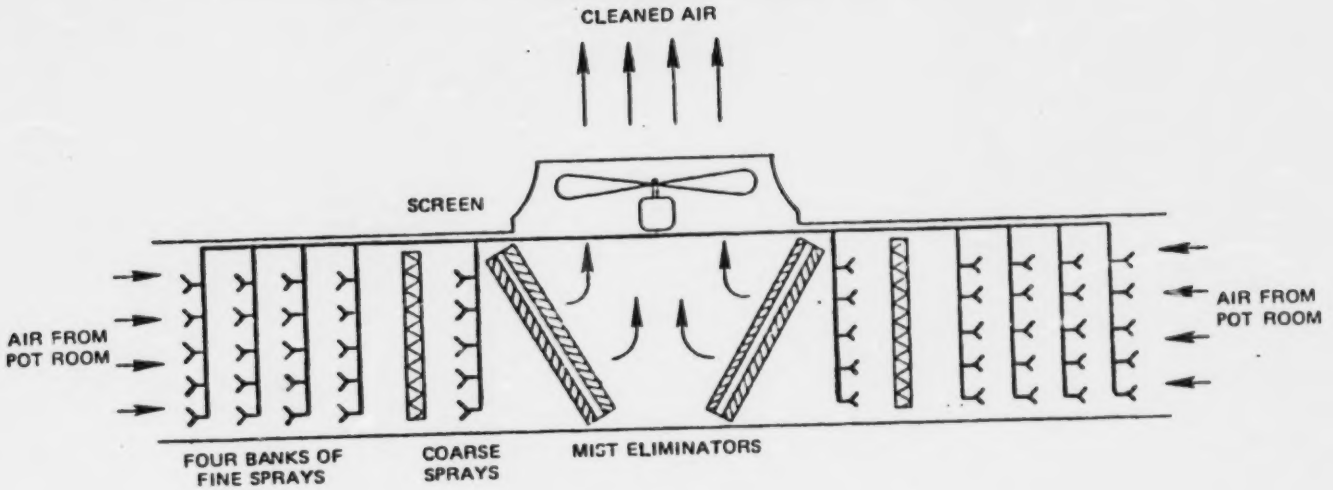

Figure 3.3 Powered cellroom spray screen scrubber.[5]

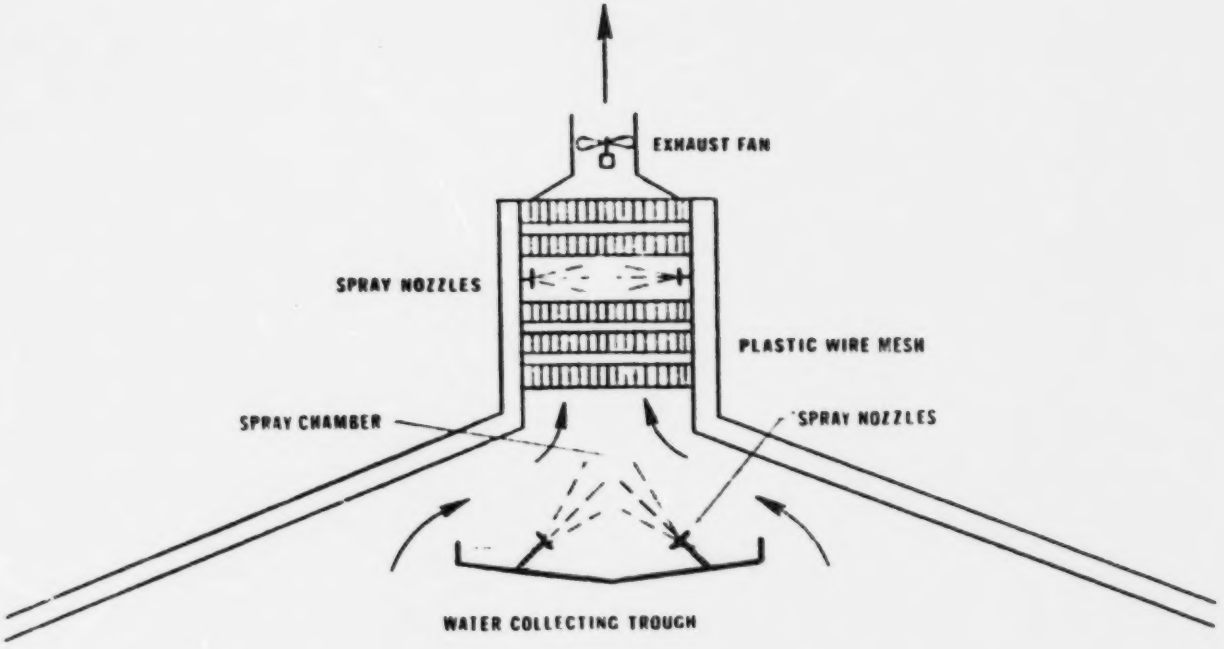

Figure 3.4 Powered monitor spray screen scrubber.[5]

of water. Liquid-to-gas ratios are three to ten gallons per 1000 cubic feet of gas. Spray screen systems have been installed at two VSS plants and a number of other types of aluminum smelters.

3.1.4 Foam Scrubber

A foam scrubber has recently been introduced for particulate control. The unit called a Centrifoam scrubber is designed and sold by Alfa-Laval AB of Sweden. Figure 3.5 illustrates the system. This system is attractive for scrubbing large gas volumes since it uses very little water.

The scrubber removes dust from the process gas stream by contacting the emission products (in this case fluorides and particulate) with a chemical foam. The foam removes large particulate by impaction, small particulate by adhesion, and gaseous products by chemical reaction.[6] Sub-micron particulates are reportedly removed almost as efficiently as large particulates. Pressure drops range from 0.3 to 1.3 inches of water.

The collected particulate flows from the bottom of the scrubber as the foam coalesces. The foam is supported at the bottom of the scrubber by a grid or gas distributor. Discharge electrodes break the foam to prevent foam from leaving the top of the scrubber.

The contaminated liquid is separated from the particulate, mixed with a foaming agent and returned to the scrubber as foam. Particulate removal efficiencies as high as 97% are claimed. Little data is available for estimating capital and operating

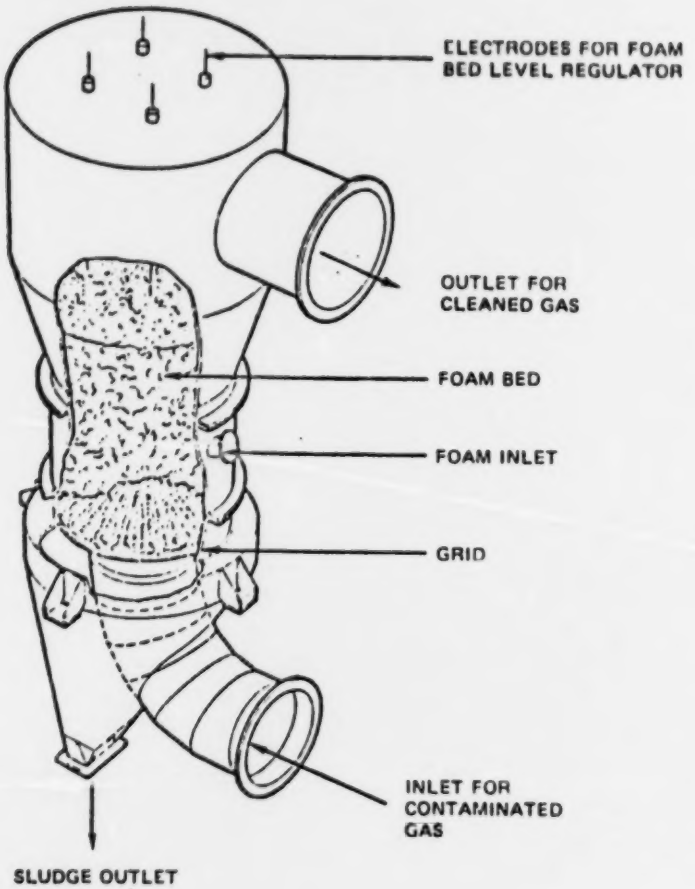

Figure 3.5 The Centrifoam scrubber.[6]

costs. However, based on scrubber configuration, costs similar to powered spray systems would be expected. Chemical foam make-up is an important and highly variable factor in predicting operating costs.

A 5000 cfm pilot foam scrubber has been installed at the Anaconda Columbia Falls smelter to determine its operating characteristics when scrubbing pot room effluent gases.

4.0 RETROFIT DESIGN - SECONDARY CONTROL SYSTEM

Of the various secondary control systems available, the powered spray screen scrubber was chosen to illustrate the feasibility of controlling pot room exhausts. This sytem represents the middle ground of secondary control systems, is more expensive than natural draft spray systems and slightly less expensive when compared to packed bed scrubbers. Fluoride and particulate removal effectiveness is also mid-range. This type of system has been installed on a number of aluminum smelter plants, including the VSS plants at The Dalles, Oregon and John Day Dam, Washington.

4.1 RETROFIT DESIGN PARAMETERS

The following parameters were used to develop a preliminary design for a secondary scrubbing system at Anaconda's Columbia Falls facility:

System	Parameters
Absorbers	Liquid-to-gas ratio 5 gal/M acfm 2,550,000 acfm/pot room or 25,500,000 for the plant 42,500 acfm per scrubber
Pressure drop	1.5 inches of water
Clarifier	½ gal/square foot rise
Clarifier bleed	5% of recirculation rate
Collection efficiency	80% for fluoride; 48% for particulates

4.2 RETROFIT EQUIPMENT OF LAYOUT

Figure 4.1 illustrates the proposed location of the secondary control system for one pot room. This retrofit layout is based upon preliminary observations of existing conditions at the Columbia Falls plant, discussions with plant personnel, and vendor representatives. The basic equipment required for the retrofit is listed in Table 4.1.

Table 4.1 RETROFIT EQUIPMENT FOR SPRAY SCREEN SCRUBBERS

Equipment	No. required	Size/capacity
Absorbers	600	42,500 acfm
Recirculating pumps	20	6400 GPM
Fans	600	42,500 acfm at 1.5 inches of water
Clarifier	1	130' diameter x 20' high
Recirculation tanks	10	15' diameter x 15' high
Miscellaneous pumps	6	----

Sixty fans will be mounted on each pot room roof monitor to draw the pot room gases through the scrubbers. Two recirculating pumps would pump limed (neutralized) water through the scrubbers. Each pump would normally service 30 units. In case of a breakdown, either pump could service all 60 scrubbers at a reduced flow rate. Make-up (fresh) and neutralized clarifier water would be fed to a recirculation tank at the end of each pot room. A portion of the recirculation water would be bled-off to the clarifier for neutralization and fluoride/particulate removal. The clarifier would be located near the present clarifiers. It is assumed that the existing lime storage and

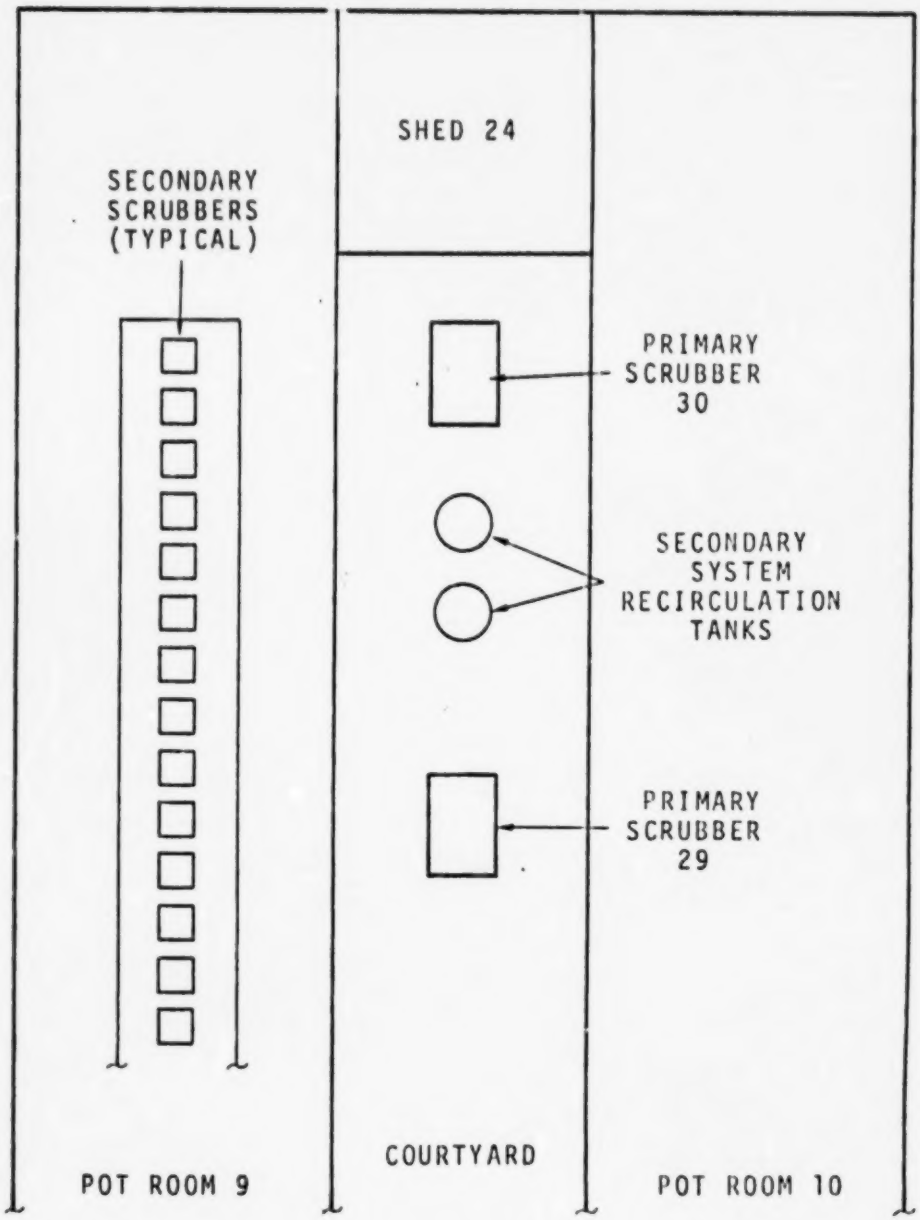

Figure 4.1 Layout of typical roof-mounted secondary scrubber.

handling system can handle the small additional requirement. The present sludge disposal equipment and areas will be used. All equipment will be made of materials resistant to fluoride corrosion.

Due to the warmth of the pot room gases, freezing in the scrubbers will not be a problem. The system will be free draining to prevent freezing in case of equipment failure. All external circulation piping will be heat traced. Pumps and circulation tanks will also be heat traced.

4.3 RETROFIT TIME SCHEDULE

A time schedule for the installation of this secondary control system is shown in Figure 4.2. It would take approximately six weeks to prepare each of the ten pot rooms for the new scrubbing system. Installing the equipment would take approximately three weeks. Final tie-in would not require any production down time. The total project would take approximately 28 months to complete after plans are finalized.

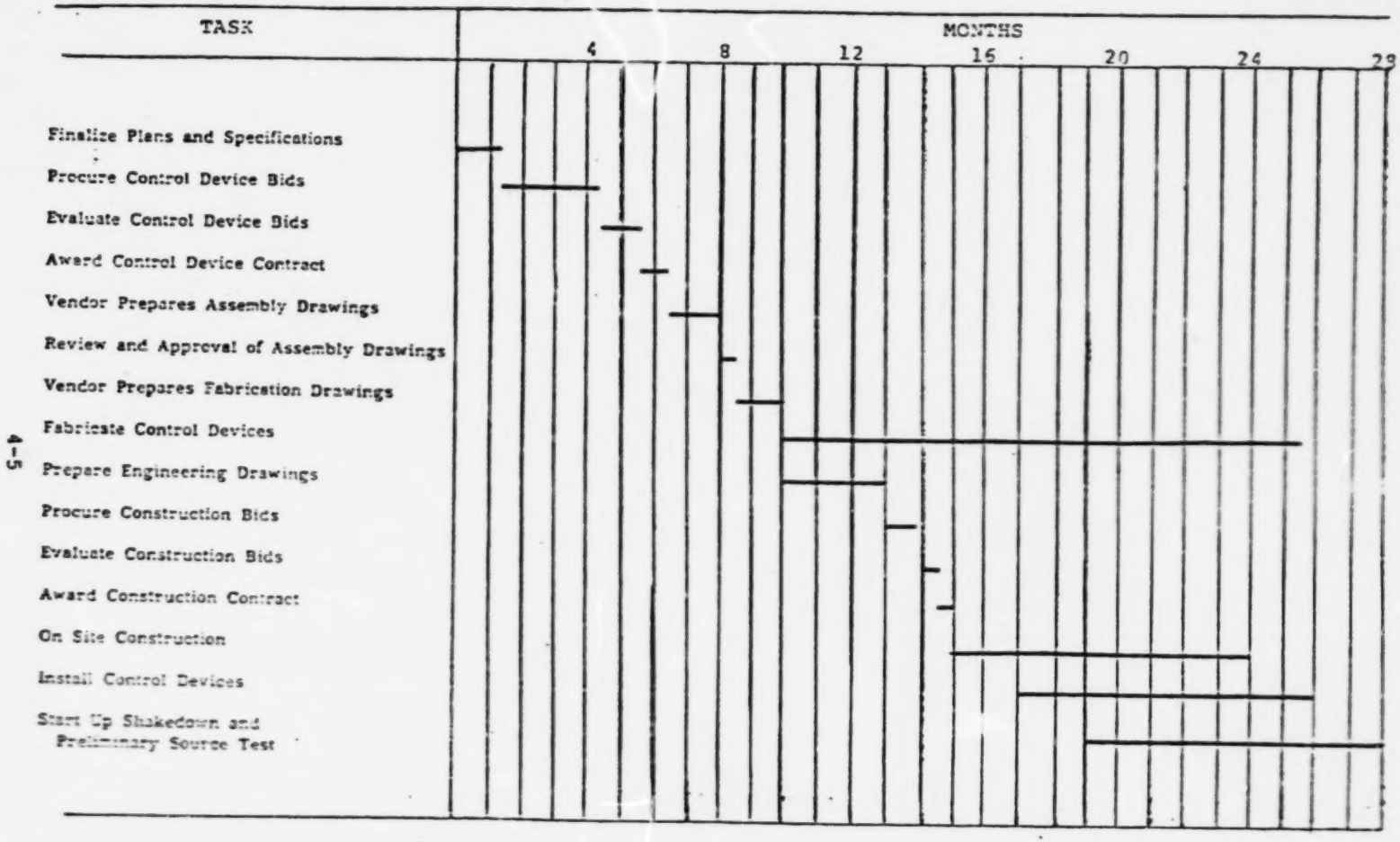

Figure 4.2 Time schedule for installing secondary control system.

5.0 COSTS

A preliminary cost estimate of the secondary control system described in this report was prepared to determine the approximate installed and operating costs for this system. These cost estimates were based upon standard engineering cost estimating procedures using verbal vendor quotes for such major equipment items as pumps, absorbers, fans, and clarifiers.

The capital cost estimate for retrofitting the Anaconda plant is $20,688,000 or about $115 per ton of aluminum capacity. Table 5.1 presents a breakdown of the capital cost estimate. The water treatment equipment included in this cost estimate amounts to approximately $500,000 or 2.5% of the total capital cost.

Annualized operating costs are estimated to be $6,114,000. Table 5.2 presents a breakdown of the annualized cost estimate. These annualized costs amount to about 1.7 cents per pound of aluminum produced. Aluminum currently sells for approximately 29 cents per pound.

Table 5.1 CAPITAL COSTS FOR ROOF-MOUNTED POWERED SPRAY SCREEN, DECEMBER 1973

Direct Costs	Material	Labor
Equipment	$4,680,000	$1,170,000
Instrumentation	300,000	100,000
Piping	1,404,000	2,106,000
Electrical	796,000	749,000
Foundations	281,000	421,000
Structural	655,000	374,000
Sitework	94,000	94,000
Insulation	140,000	328,000
Painting	19,000	94,000
	A = $8,369,000	B = $5,436,000

Sub-Total, Direct Costs, C = A + B			$13,805,000
Indirect Costs			
Interest during construction	0.093 C	= $1,284,000	
Contractor's fee and expenses	0.10 C	= 1,380,000	
Engineering	0.10 C	1,380,000	
Freight	0.025A	= 209,000	
Offsite	0.03 C	= 414,000	
Taxes	0.03 A	= 251,000	
Spare Parts	0.01 A	= 84,000	
Sub-Total, Indirect Costs, D			$ 5,002,000
Contingency	0.1 (C+D) =		$ 1,881,000
	Grand Total =		$20,688,000

Table 5.2 ANNUAL OPERATING COSTS FOR ROOF-MOUNTED POWERED SPRAY SCREEN

Raw Material	Quantity	Unit Cost	Annual Cost,$
Lime	136 lb/hr 8760 hr/yr	@$0.0275/lb.	33,000
Utilities			
Water	5500 GPM 8760 hr/yr	$0.20/M Gal	10,000
Electricity	15,400 KW 8760 hr/yr	6.75 mills/KWH	911,000
Operating Labor			
Direct			
1 man/shift	3 men/day	5.50/hr/man	48,000
Supervision	15% of direct labor		7,000
Maintenance			
Labor and materials	3% of fixed investment		621,000
Supplies	15% of labor and material		93,000
Overhead			
Plant	50% operation and maintenance		384,000
Payroll	20% operating labor		10,000
Fixed Costs			
Depreciation ($\frac{100}{15}$) = 6.67 Interim replacement (0.35%) Insurance (0.3%), Taxes (4%) Capital cost (8%)	= 19.32% of fixed investment		$3,997,000
	Total annual cost		$6,114,000

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